Safford Mine

2007 – 2008 Groundwater Monitoring Report

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1.0 Introduction

This report summarizes and presents an evaluation of the Model, Monitor, and Mitigate (3M) Program for the Dos Pobres/San Juan Project (Safford Mine). This evaluation was done in accordance with the Dos Pobres/San Juan Project Clean Water Act Section 404 Mitigation and Monitoring Plan (MMP), described in the Dos Pobres/San Juan Project Final Environmental Impact Statement (FEIS) (Section 3 of Appendix F of the FEIS; BLM, 2003). This report was prepared for Freeport-McMoRan Safford Inc. (FMSI) by AquaGeo, Ltd., with technical assistance from Clear Creek Associates and Dr. Robert Mac Nish.

The 3M Program was devised to assist in evaluating effects of groundwater pumping at the Safford Mine and the adequacy of measures implemented to mitigate such effects. The 3M Program involves the use of statistical measures in a series of tests using water level data from specified groundwater monitoring locations. Each statistical measure, or 3M Statistic, is evaluated against a set of criteria, or 3M Criteria. The sets of 3M Criteria establish bounds for each statistical test, and depending on whether a statistic falls in or out of the range of specified bounds, a decision is identified regarding required actions based on the overall evaluation of the 3M Program.

A component of the 3M Program is a three-dimensional computer model of groundwater flow (URS Corporation 2002), known as the 2002 FEIS Model. The purpose of the model is to provide interpretation of water level data obtained from numerous piezometers and monitor wells in and around the Safford Mine (**Figure 1**) and to predict future impacts, if any, of the current and planned mining operations on groundwater flow to or from the Gila River, Bonita Creek and the San Carlos Apache Reservation. The model is calibrated in both steady-state and transient modes to observed conditions.

There are five groups of monitoring wells included in the 3M Program. The 47 wells, with Group numbers, are shown on **Figure 2**. The wells are grouped geographically and hydrogeologically based on their locations relative to the mining and production well pumping areas, or relative to the Gila River, which is located approximately eight miles to the south of the mine.

- Group 1 wells are located between the mining operation and the Gila River and are a critical component of the 3M Program. Four wells (LBF-01, LBF-02, LBF-03 and LBF-04) are screened in the Lower Basin Fill, and two wells (LBF-01d and LBF-02d) are screened in bedrock beneath the Lower Basin Fill. Although LBF-01d and LBF-02d are in Group 1, they are not included in the tests of the 3M Program because they are not completed in the Lower Basin Fill (see Section 6).

- Group 2 wells are located similar to Group 1 wells, but occupy a more extensive area. These wells monitor water levels in either Upper or Lower Basin Fill, or bedrock.

- Group 3 wells are located northeast of the Butte Fault (these wells are included in the 3M Program for general information, but are not included in the 3M decision process). All wells in this group are screened in bedrock.

- Group 4 wells are located northwest of the Graben structure formed by, and situated between, the Butte Fault and the Valley Fault. Wells in this group are screened in bedrock. The production

wells that provide water for the mining operation are located in the Graben structure to the southeast of the Group 4 wells[1].

- Group 5 wells are located between the mining operation and the San Carlos Apache Reservation boundary to the northwest and Bonita Creek to the northeast. Wells in this group also are screened predominately in bedrock.

Table 1 provides a summary of the following for wells in the 3M Program: group number, well name, coordinates, altitude of land surface, depth of open intervals, corresponding model layer and water level measured prior to when mining commenced. In addition, **Table 1** provides summary information for wells from which water samples were collected (Section 4.4).

2.0 Purpose and Scope

The purpose of this 3M evaluation is to monitor the performance of the 3M Model in simulating the effects of actual pumpage on an annual basis. The 3M Model is a revised version of the 2002 FEIS Model (see Section 5.0 below). The 3M evaluation relies on water level measurements obtained from wells in the vicinity of the Safford Mine. The results of this evaluation are used to assess whether or not the current model requires recalibration to bring the model projections into closer agreement with the conditions observed in the field. The model is used to predict potential future effects on the regional groundwater system and to guide the implementation of mitigation measures to offset the effects of the mine pumping on the flow of the Gila River. The time immediately preceding August 2007 through June 2008 is called the "evaluation period" for the current 3M evaluation (see Section 4 below for additional detail). The scope of this report is to include the available water level data for the 37 wells (Groups 1, 2, 4 and 5) for the evaluation period[2]. The compiled data have been used to calculate differences between model-projected water levels and gradients with those collected by, or estimated from, physical measurements obtained from the 3M monitoring program. Information developed from the four well groups and the 3M Model are used in a decision process illustrated in Figure 11 of the MMP (**Attachment 1** of this report), titled "Schematic Flow Chart of the Groundwater Model, Monitor, and Mitigate Process" (note the attached figure has been annotated (shown in red) to identify test numbers described in Section 6.0).

3.0 Background

The Safford Land Exchange between Phelps Dodge Corporation (now Freeport-McMoRan Corporation) and the Bureau of Land Management (BLM) was completed in September 2005. Following the receipt of the remaining environmental permits, Phelps Dodge Safford, Inc., now FMSI, began construction of the Safford Mine in August 2006. Mining operations in the Dos Pobres pit began in August 2007.

During 2006, groundwater pumping for construction water was accomplished by installing relatively small horsepower (HP), temporary pumps in two of the production wells, GI-P1 and GI-P4 (refer to

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[1] Shaft 1produces groundwater from the Graben structure as discussed in Section 5

[2] Water level data are presented for LBF-01d and LBF-02d but not used in any 3M tests (see Section 6)

Figure 2 for wells and locations). A larger HP pump was also installed in existing Shaft 1 in the spring of 2007. By the fourth quarter of 2007, permanent pumps with greater HP were installed in production wells GI-P1, GI-P2, and GI-P4. Also during the fourth quarter of 2007, water was used to pre-wet the crushed/screened over-liner fill and run-of-mine rock layers on top of the leach pad liner in advance of leaching activities. Crushed ore agglomerated with water and acid was placed on the leach pad for the first time near the end of November 2007. Shortly thereafter, water and acid were applied to the material by drip lines. Prior to this time, most of the water produced at the mine was used for dust control and, to a lesser extent, other construction-related work, such as moisture conditioning of the leach pad under-liner materials. The first production of copper cathode from the electrowinning tank house occurred on December 26, 2007.

Implementation of the Alternate Year Fallowing Plan (see Section 3.3.3 of Appendix F of the FEIS) commenced in January 2008, with the fallowing of 200 acres of farmland near the Gila River in the Sanchez area (those fields are identified in **Attachment 2** of this report).

4.0 Data Summary

This section provides a summary of the data available for the 2007-2008 3M evaluation. The evaluation includes groundwater production rates, groundwater levels, and water chemistry data through June 2008.

4.1 Groundwater Production Rates

Table 2 lists the estimated rate of pumping on a month-by-month basis for the mine in gallons per minute (gpm). Prior to December 2007, the average monthly rate was estimated based on periodic field meter readings of pumped volumes. Starting December 2007, the values listed are average rates for each month based on pumping rates that were automatically recorded and digitally saved at regular intervals by FMSI. The average pumping rates were derived from the pumping records by calculating the total volume pumped, in gallons, for each month and dividing the value by the total number of minutes in the corresponding month.

Figure 3 shows the monthly average pumping rate for each production well over time since March 2006, when site preparations began. Groundwater pumping through November 2007 was relatively small, typically ranging up to 100 gpm. Mining commenced in August 2007, and was followed by a substantial increase in pumping beginning in December 2007, as leaching operations started. Since that time, average monthly pumping increased to a maximum of just over 2,500 gpm in June 2008.

4.2 Water Levels

Water levels for this report were measured manually and were obtained from the U. S. Geological Survey (USGS) internet site:

http://nwis.waterdata.usgs.gov/nwis

In addition to this data, water level measurements taken with pressure transducers installed in the Group 1 wells were also used and likewise obtained from the USGS[3]. Water level hydrographs for wells in each of the five groups of the 3M Program are shown in **Figures 4** to **14**.

From the hydrographs, it is apparent that the measured water levels fluctuate over time in every well of the 3M Program. These fluctuations typically occur over durations of less than a day to several months. For example, during the month of June 2007, water level fluctuations in LBF-01 (Group 1) ranged in magnitude from approximately 0.02 to 0.2 feet; whereas, longer term fluctuations at the same location in 2007 ranged in magnitude from approximately 0.2 to 0.4 feet. These natural fluctuations can hide or mask small changes in hydraulic gradients and drawdown caused by pumping.

There are 44 wells in the 3M Program with data on which to base a reasonable interpretation of long-duration trends. These water level trends over the last several years indicate two distinct patterns (**Table 3** summarizes the short and long-duration trends for each of the 47 wells[4] in the five groups in the 3M Program, as well as the change for the evaluation period):

> ➤ Pattern 1- Characterized by rising water levels in many of the wells completed primarily in basin fill south and southeast of the mine. Exclusive of wells with unusual fluctuations, the magnitude of the net rise varies from approximately 0.2 foot at RB-1 to approximately 2 feet at DPW-11[5]. This pattern is observed in 23 of the 44 wells, including all Group 1 wells, most of the Group 2 wells, and two deep wells, RB-1 and G5-02 (Group 5), which are completed in bedrock to the north of the Butte Fault and are separated by a distance of approximately 10 miles.

> ➤ Pattern 2 – This distinct pattern is associated with a long-term trend of decreasing water levels, and is observed in 18 of the 44 wells. For the most part, this pattern of decline is observed in bedrock wells located near to or south of the Butte Fault and is best represented in AP-32 (**Figure 10**).

Water-level trends in three of the 44 wells exhibit either a combination of rise and decline or no clear long-duration trend at all. For most but not every well in the 3M Program, the general pattern of either water level decline or rise was clearly observed before mining began with the pattern generally continuing afterwards. These observed water level trends, therefore, represent ongoing natural fluctuations in the groundwater system (**Figures 4 to 14** and **Table 3**). At this point, there has not been

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[3] Email from Nicholas Paretti of USGS to Peter Sinton of AquaGeo, 2008. The manual water-level measurements were collected by the following personnel: during 2005 - James Brown and Bruce Gungle of the USGS, and Mike Price and Chad Allen of Allen Pump Company (subcontractors to FMSI); during 2006 - Bruce Gungle of the USGS, and Mike Price and Steve Allen of Allen Pump Company; during 2007 - Nicholas Paretti and Bruce Gungle of the USGS, and Steve Allen and others of Allen Pump Company; during 2008 - Nicholas Paretti and Bruce Gungle of the USGS, and Steve Allen of Allen Pump Company. The transducer water-level measurements were collected by Steve Allen of Allen Pump Company.

[4] Three wells in the 3M Program, AP-01, AP-3A and AP-21 have unusual water-level fluctuations or have no data available for evaluating long-duration trends; thus 44 wells are evaluated with regard to long-duration trends.

[5] **Table 3**, values listed under "Long-Duration Water Level Fluctuation". A rise in water level is a positive value.

enough groundwater removed from the system to be able to discern pumping effects, except in the immediate vicinity of the production wells. If mining-related drawdown at 3M Program wells exceeds the observed natural range in fluctuations, or affects natural water level trends, it will be possible to compare observed drawdowns with those predicted by the model.

For each well in the 3M Program, an estimate of the net change in water level between July 2007 and June 2008 has been calculated (see **Table 3**). The estimated net changes in water levels from July 2007 to June 2008 are shown on **Figure 15**.

Water level measurements at the Group 1 wells indicate that natural fluctuations occur at the same time and over about the same magnitude in Lower Basin Fill (LBF-01 and LBF-02) and in the deeper bedrock (LBF-01d and LBF-02d) (**Figure 4**).

4.3 Springs

The MMP provides a description of springs in the 3M Program (**Figure 2**), and predicts that springs near the mine will not be influenced by groundwater pumping related to mining. There are a number of reasons for this prediction:

1. The springs most likely to be affected are the four springs nearest the mine (Bryce, Cottonwood, Hackberry, and Walnut). These four springs are at an elevation between 4,200 to 4,300 feet, more than 1,000 feet higher than groundwater levels in the Graben structure, and all occur on the upper surface of a moderately strong ledge-forming layer of volcanic rock, suggesting that the discharge from these springs is derived from localized zones of perched groundwater.

2. Discharge from the springs is highly variable (**Table 4**), and related to seasonal fluctuations in precipitation, suggesting that the ultimate source of the spring water is recharge that occurs in close proximity to the springs. This hypothesis is supported by the highly variable discharge, including drying, observed at the springs, and by isotopic data (see Section 4.4 below), which suggest that the spring water is very young.

3. The Butte Fault hydraulically separates the springs from the groundwater in the Graben structure that the mine is utilizing for its water supply. The influence of the fault, which is discussed in detail in the 2002 FEIS Model report (URS Corporation 2002), results in a large difference in water levels on either side of the fault. Groundwater levels on the north side of the Butte Fault are about 800 feet higher than groundwater levels on the south side of the fault. This large difference in water levels is indicative of the hydraulic separation. Empirical evidence in support of the effectiveness of the Butte Fault as a barrier to groundwater flow was revealed during excavation of the underground workings beneath the Dos Pobres area. The excavation of Shaft 1 (north of the Butte Fault) and drifts from this shaft required little pumping to maintain dry conditions until drifts pierced the Butte Fault. When the fault was pierced, groundwater inflow from the Graben structure immediately required a large increase in pumping to keep the workings dry.

4. With the extremely small permeability of the Butte Fault, if the rock units between the surface exposure of the Butte Fault and the rock units underlying the springs were fully saturated, some

springs and seeps should occur along the trace of the Butte Fault. In the absence of such springs and seeps, it is likely that unsaturated conditions prevail in the bedrock underlying the springs and above the surface exposure of the Butte Fault.

The other five springs (**Figure 2**), which are even farther from the mining area, occur at elevations about 300 or more feet higher than the four springs closest to the mine pumping area.

Table 4 lists the measured or estimated amount of discharge at the six springs included in the 3M Program[6]. In several cases the amount of discharge could not be measured due to the presence of a "springbox". A springbox is a small basin built to retain discharge from the spring, which can also capture surface runoff, making discharge estimates difficult or impossible. At such locations, the amount of estimated discharge may be affected by the rate of evaporation or by consumption by wildlife or livestock.

The small amount of discharge (or often dry conditions) recorded at some of the springs is probably due to the small rates of recharge resulting from precipitation occurring over upgradient bedrock areas, coupled with the limited area over which recharge occurs. All available information, including that collected since publication of the FEIS, is consistent with the hypothesis put forward in the MMP regarding the isolated, perched and localized nature of the groundwater supplying the springs.

4.4 Water Chemistry

Water chemistry samples were collected from wells in the area of the Safford Mine at locations shown on **Figure 16**. Samples were obtained from 14 wells and 4 springs in 2005 and from 15 wells and 6 springs in 2007 to establish baseline conditions prior to the commencement of mining operations. The water chemistry data for this report were downloaded from the USGS web site (see Section 4.2), or were obtained from the USGS[7]. A summary of the water chemistry data is provided in Appendix A. Data for samples taken from Well AP-25 is listed in Appendix A, however, no analysis of this data is presented because water in well AP-25 is impacted by historic operations of the San Juan mine.

Anions and Cations

Anion and cation concentrations from the 2005 and 2007 sampling events are plotted on piper diagrams (**Figures 17** and **18**) and stiff diagrams (**Figures 19** and **20**). Four water types have been identified based on the major-ion groundwater chemistry data (see **Figures 19 and 20**).

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[6] Spring data was collected by the same personnel that collected water-chemistry data (Section 4.4).

[7] http://nwis.waterdata.usgs.gov/nwis. The water-chemistry samples were collected by the following personnel: during 2005 - James Brown and Bruce Gungle of the USGS, and Steve Allen of Allen Pump Company; during 2007 - Nicholas Paretti and Bruce Gungle of the USGS, and Steve Allen of Allen Pump Company.

- Type 1 type water (Na+K, Cl) was present at AP-26, AP-27, and AP-29 in the mountain-front pediment and at AP-01 near the northern FMSI property boundary.

- Type 2 type water (Na+K, HCO_3) was present at AP-09, AP-11 and AP-23, and Pothole Spring (data only available for 2007).

- Type 3 type water (Ca+Mg, HCO_3) was present at AP-05, AP-14 (data only available for 2005), AP-22, DPW-01, DPW-02 and all springs sampled except Pothole Spring (4 springs in 2005 and 5 springs in 2007).

- Type 4 type water (Na+K, SO_4) was present at AP-21, which is located east of the San Juan pit.

It should be noted that the water type at DPW-06 changed from Type 2 to Type 4 between the 2005 and 2007 events. Although HCO_3 and Cl concentrations were similar for each sampling event, sulfate increased from 7.3 mg/L in 2005 to 270 mg/L in 2007, which resulted in the change.

Stable and Radioactive Isotopes

Groundwater samples were analyzed for the stable isotopes carbon-13, oxygen-18, and deuterium and the radioactive isotopes carbon-14 and tritium. Delta oxygen-18[8] and delta deuterium[9], as plotted on **Figure 21**, lie below the global meteoric water line[10], suggesting that a strong evaporative effect has resulted in the local meteoric water line (during evaporation, heavier isotopes remain in liquid water in greater concentrations).

The groundwater samples generally have more carbon-13 than typically found in modern organic matter (biological systems tend to concentrate carbon-12 and omit carbon-13). This suggests that a source of inorganic carbon, typically carbonates in soil or rock, has contributed to the concentration of this isotope in the samples. Similarly, the carbon-14 concentrations in water samples have likely been influenced by sources of inorganic carbon, which may also contain carbon-14. Water concentrations of carbon-14 may be enhanced by dissolution of carbon-14 bearing carbonate minerals.

In all samples except the ones from DPW-02, spring water has a smaller carbon-13 concentration than groundwater indicating that the source of the spring water is relatively young (**Figure 22**). This also suggests that the groundwater samples are from a system in which the groundwater is older and has traveled farther than the spring water.

Beginning in 1953, aboveground nuclear testing resulted in a spike in atmospheric tritium concentrations. Tritium has a short half-life of 12.43 years. The presence of elevated tritium concentrations in

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[8] "Delta oxygen-18" is a measure of how much oxygen-18 there is in a sample relative to a standard amount, and is a function of ratios of the two isotopes, oxygen-16 and oxygen-18.

[9] "delta deuterium" is a measure of how much deuterium (hydrogen-2) there is in a sample relative to a standard amount, and is a function of ratios of the two isotopes, hydrogen-2 and hydrogen-1 .

[10] A meteoric water line represents typical conditions for precipitation for a certain area.

groundwater typically indicates that the groundwater is very young (post-1952), which could result from either a short residence time in the subsurface, or a mixing of localized infiltrated surface water with older groundwater.

In general, the water chemistry isotope data support the hypothesis that the springs are derived from small, perched groundwater systems that will not be affected by pumping related to the mine. On average, water samples from springs contain approximately 3 times more carbon-14 than water samples from monitoring wells (based on combined data from 2005 and 2007 samples). Similarly, average tritium concentrations in water samples from the springs are approximately double the average concentration in water samples from monitoring wells (based on combined data from 2005 and 2007 samples). The delta carbon-13 values for the springs are, for the most part, consistent with the carbon-14 and tritium concentrations, having smaller values (more negative) than samples from monitoring wells. Together, these findings suggest that the spring water is younger relative to the groundwater, at or near the regional water table.

Statistical Evaluation

A statistical evaluation was performed to test the hypothesis that spring water and groundwater are significantly different based on the available data. Due to the limited amount of data, the Wilcoxon-Mann-Whitney (WMW) statistical method, also known as the Wilcoxon Rank Sum test, was used. This is a nonparametric test used to test the equality of the means of two samples (Singh and others 2010). The data are sorted according to the magnitude of the measured value, and then each unique value is assigned a numeric rank. A bar chart of the resulting ranks may reveal any obvious non-random groupings; if one group clusters in one part of the bar chart, it is likely that the two groups have different means and are thus from different populations. In the case of spring water versus groundwater, the results would indicate whether or not the two waters are statistically similar.

The evaluation was performed for pH and Carbon-14, and includes all available data for these parameters except results for AP-25 and pumping well GI-P1. The pH of rainwater in the area of the mine is approximately 5.25[11]; the pH of groundwater varies according to distance from the point of recharge and the type of water-rock interactions that occur along the path of groundwater flow. Unless there are geochemical reactions occurring that cause the pH to decline below that of the pH of rainwater, the pH of the groundwater will rise above that of rainwater due to consumption of acidity by carbonate and other acid-neutralizing minerals. Measurements of pH in groundwater samples from springs and wells indicate that acid neutralization dominates the geochemical environment. Therefore, it is likely that pH is an indicator of distance from the point of recharge. Carbon-14 is a reasonably direct indicator of the age of a groundwater sample; less Carbon-14 in a water sample generally indicates that the water has traveled farther from the point of recharge. Groundwater and spring water pH for 2005 was formatted into a dataset for statistical analysis using ProUCL Version 4.00.05 (Singh and others 2010). This process was

[11] Based on 2004 National Atmospheric Deposition Program/National Trends Network information for field pH of rainwater samples; available from http://nadp.sws.uiuc.edu/maps/Default.aspx

repeated for pH data from the 2007 and 2009 sampling events, and for each year of Carbon-14 data. A summary bar chart similar to the one used for the MW test was prepared to illustrate clustering and summarize the WMW test results.

Results of the MW tests are summarized in **Figures 23** and **24**, and in **Table 5**. In these figures, the average of 2005, 2007 and 2009 values for each location is plotted to simplify presentation and the WMW statistical results are summarized. In both figures, springs tend to plot in one area of the bar charts, which suggests distinct differences between groundwater and spring water. The spring with pH most similar to groundwater occurs at Walnut Spring where groundwater flows from volcanic rock through surficial sediments before discharge at the location of the spring which likely causes a reduction of acidity as groundwater interacts with acid-neutralizing minerals in the sediments. The distinct differences between groundwater from wells and spring water are quantitatively supported by the results of the WMW tests. The results for carbon-14 and pH definitively support the hypothesis that groundwater and spring water are different.

5.0 Groundwater Model for 3M Program

The 3M plan requires that predictions of the effects from actual mine pumping on the groundwater system be made using a groundwater model. For this study, the groundwater model developed for the FEIS (URS Corporation 2002), known as the 2002 FEIS Model, was slightly modified in order to perform the appropriate simulations. The modified 2002 model is referred to as the 2008 3M Model.

The 2002 FEIS Model and the current 3M model simulate long-term average recharge, which originates as infiltration of precipitation and runoff. The observed small rise in water levels in most areas in the vicinity of and to the south of the mine, except in close proximity to the pumping wells, is probably due to the observed recent steady increase in precipitation (based on data obtained from the National Climate Data Center for Safford Airport[12]), which results in more groundwater recharge. Although the model predicted very small water level declines over the 3M evaluation period, actual water levels over the same time period were observed to be rising slightly in 21 of the 47 3M Program wells (trends in three wells, AP-01, AP-3A and AP-21, cannot be evaluated; see Section 4.2). If the water level declines predicted by the model actually occurred in this area, the changes driven by natural events were larger, and have obscured any effects mine pumping may have had.

To prepare the model for the current 3M evaluation, the following modifications were made to the 2002 FEIS Model:

- The 2002 FEIS Model was translated from the original MODFLOW model datasets into Groundwater Vistas version 5 (Environmental Simulations 2007). Groundwater Vistas is a pre and post-processing program used for developing, maintaining and executing MODFLOW simulations. The only change made to the model during this translation was to the units of time and distance used in the model. The units of the 2002 FEIS Model were converted from meters

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[12] Data was obtained for the period from 2005 to 2009
(http://cdo.ncdc.noaa.gov/ulcd/ULCD?state=AZ&callsign=SAD)

and days, to feet and days. The version of the USGS computer simulator MODFLOW96 (Harbaugh and McDonald, 1996), similar to that used in the 2002 FEIS Model, was also used in the Groundwater Vistas implementation of the 3M Model for consistency. This translation was done to simplify model computational processing.

- Three simulations were prepared from the translated model. The first is a steady-state simulation of pre-mining conditions. This simulation is essentially a re-run of the 2002 FEIS Model to obtain initial hydraulic-head conditions for subsequent transient simulations. Because the 2002 FEIS Model was calibrated to steady-state conditions characterized by water levels available through June 1996, all transient simulations start in June 1996. The second simulation is a transient prediction for the period of time from June 1996 to June 2008. This period of time includes pre-mining groundwater pumping conducted for the purposes of large-scale testing or water supply. The third simulation is a transient prediction for the same period of time as the second, except that no pumping for mining operations is included. This third simulation provides the hydraulic head data for the groundwater system without mine-related pumping stresses, which is needed for calculating the predicted drawdown due to mining. This was accomplished by subtracting predicted water levels with mine pumping from those without pumping[13]. The second and third predictive simulations are referred to as "pumping" and "non-pumping", respectively.

- The transient simulations are based on stress periods of one month in length. The total number of stress periods is 145. Each stress period is simulated using five time steps of varying length (shortest at the beginning of the month).

- For each stress period, the average rate of pumping was specified at each pumping well based on FMSI records. Section 4.1 provides a discussion of pumping rates and their estimation. **Table** 5 provides a listing of pumping rates simulated in the 3M Model at each location by month.

- Initially, the 3M Model was executed without any modification to hydraulic properties or to the boundary conditions of the 2002 FEIS Model. However, during trial runs, it was evident that simulated pumping from Shaft 1 resulted in unrealistic drawdown near the shaft such that the full amount of pumping from Shaft 1 could not be accounted for in the trial simulations. The pump in Shaft 1 draws water from old drifts (tunnels) which pierce the Butte Fault at several locations, hydraulically connecting Shaft 1 with groundwater in the Graben. To remedy the situation, so that the model better simulated the distributed effects of the pumping, the hydraulic conductivity of model cells in the vicinity of the old drifts surrounding the shaft was increased from approximately 2×10^{-4} ft/day to 15 ft/day based on subsequent trial testing. The zone of increased hydraulic conductivity spans model layers 10 to 14 and covers an area of less than 570 acres (0.2% of the model area). The effect of this modification was that Shaft 1 was drawing water more directly from many model cells other than the one in which Shaft 1 was located, as it is in the real system (the drifts allow the pump in Shaft1 to draw water in from all the materials

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[13] It is likely that if pumping from the pre-mining period were included in the model-predicted drawdown and subsequently used in 3M Tests, the conclusions of the overall 3M Program would not change.

penetrated by the drifts). The effect of this small modification on model performance and results is only significant near the shaft (sensitivity analyses performed on the 2002 FEIS Model tested the effect of much larger deviations from the calibrated configuration).

Except as noted above, no other changes were made to the 2002 FEIS Model to obtain the current 3M Model used for this report. No recalibration of the 2002 FEIS Model was performed to obtain the current 2008 3M Model.   After running the transient pumping and non-pumping simulations, predicted drawdown was calculated for subsequent 3M calculations.

6.0 Implementation of the 2007-2008 3M Evaluation

Evaluation of the 3M Criteria requires comparisons of observed and modeled elevations of groundwater at specified monitoring wells. These wells, along with the 3M group numbers, are shown on **Figure 2**. Each 3M Statistic to be estimated from the water levels is described in Section 3.3.1.3, "Data Analysis" of the MMP. The evaluation of the program is achieved through a decision process that comprises a series of tests. The specific tests, along with numerical values of the 3M Criteria, are described in Figure 11 of the MMP (**Attachment 1**). An additional test, called for in Section 3.3.1.3, fourth paragraph, of the MMP, has been included and applies only to this initial annual 3M evaluation (referred to as "Test 0" in this document).

The influences on measured water levels from groundwater pumping for mining purposes and from natural background fluctuations are incorporated into both the measurement-based estimates of changes in water levels and in hydraulic gradients generated for each of the 3M tests. For monitoring locations where the natural water level fluctuations are significant, the influence of mine pumping may be a small to immeasurable component of the measurement-based estimates of change. In fact, the component related to the pumping may not be discernable from direct measurements, especially in areas distant from where the pumping occurs. The difficulty in assessing these small groundwater pumping effects on the aquifer system is the primary purpose for utilizing the 3M Model.

It must be noted that the 3M Program (BLM, 2003) indicates that the focus of the Group 1 wells is the Lower Basin Fill, the most permeable aquifer between the mine and the Gila River. The program also indicates that the purpose of the deep well pair is to monitor conditions in the bedrock beneath the Lower Basin Fill for model calibration purposes (particularly the vertical gradient between the bedrock and overlying Lower Basin Fill). According to well logs and construction information, LBF-01d and LBF-02d are completed in and monitor bedrock just below the Lower Basin Fill. The monitoring intervals of the wells are sealed off from the Lower Basin Fill so that water levels in these two wells are representative of the bedrock beneath the Lower Basin Fill. In addition, due the smaller permeability of the bedrock relative to that of the Lower Basin Fill, any hydraulic influence from the mine pumping in these wells would probably be transmitted to the deep Group 1 wells through the overlying Lower Basin Fill. Therefore, wells LBF-01d and LBF-02d are not included in the 3M calculations.

Each test of the 3M Program corresponds to a specific test in the flowchart shown in Figure 11 of Appendix F of the FEIS (**Attachment 1**), with the exception of Test 0. Boxes on the left side of the flow chart are numbered Test 1 and Test 2, whereas corresponding boxes on the right side are numbered 1A and 2A. Diamond shapes on the figure list the established 3M Criteria upon which each test is evaluated.

It should be noted that, according to the MMP, the criteria listed in the diamond shapes are doubled for this initial annual evaluation. Each of the applicable tests is discussed in detail in the following subsections.

6.1 Description and Results of 3M Test 0

Test 0 is intended to evaluate the calibration of the 2002 FEIS Model based on the new data collected since that model was completed. Test 0 relies on new measured water level data from the Group 1 wells and the simulated, steady-state water level at the same location. The test includes two parts: (A) a comparison between measured and modeled water levels, and (B) a comparison between measured and modeled hydraulic gradients. In the first comparison, Comparison A, the modeled water levels should be within 30 feet of the average measured water levels for each well in Group 1. In the second comparison, Comparison B, the modeled hydraulic gradient between wells of Group 1 should be within 25% of the hydraulic gradient calculated from water level measurements among two well pairs: LBF-01/LBF-02 and LBF-03/LBF-04.

For Comparison A of Test 0, modeled water levels are within 30 feet of the average water level based on measured values and are, therefore, within acceptable limits for the Group 1 wells[14]. For Comparison B, modeled hydraulic gradients are greater than the 25% criterion for hydraulic gradients estimated from averaged water levels at the Group 1 wells. The reasons for the criteria exceedance include:

- Natural water-level fluctuations at each Group 1 well are of a magnitude similar to the calculated difference in water levels between each pair of wells. It must be noted that the hydraulic gradient for each pair of wells is calculated by dividing this difference in water levels between each pair of wells by the distance between the wells. Based on the calculated hydraulic gradients between the three pairs of Group 1 wells, the hydraulic gradient prior to mining ranges from 6×10^{-5} to 1×10^{-4} ft/ft, which corresponds to differences in average water levels for each pair that range from just 0.25 to 0.38 ft. Because the observed natural fluctuations in water levels at the six Group 1 wells are of similar magnitude, the natural variation in hydraulic gradient between the three pairs of wells is greater than 25%.

- At the time that the 2002 FEIS Model was calibrated, the water level data available then suggested that hydraulic gradients in the vicinity of the Group 1 wells were approximately six times larger than subsequently estimated based on the data now available for the of Group 1 wells.

As a result, the Test 0 gradient criteria were too narrowly specified for site conditions in the vicinity of the Group 1 wells. In addition, the model passes the more important gradient test that focuses on the changes over time (see Test 1A, Section 6.3). It is therefore reasonable and prudent to ignore the results of Test 0 Comparison B, and to follow the intent of the 3M Program and allow two more years of mining to occur before any recalibration of the model is performed according to future evaluations of the 3M Program. **Table 6** provides a summary of results for Test 0.

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[14] The averages are calculated from water level data available for the period August 1, 2006 to July 31, 2007, prior to the onset of mining.

6.2 Description and Results of 3M Test 1

Test 1, which only applies to Group 1 wells, focuses on water level changes in the Lower Basin Fill between the mine and the Gila River. Test 1 is intended to evaluate the difference between two values for each Group 1 well, with each value representing an estimate of the influence of mine pumping on groundwater levels. The first value is calculated from measured groundwater levels, whereas the second value is a projection from the 3M Model. Both values represent a change in water level between pre-mining conditions and conditions during mining at the end of the evaluation period. For each well, the difference between the two values is the statistical measure of Test 1. To meet the statistical requirements of Test 1, the difference between the modeled and measurement-based values must be 10 feet or less. According to the 3M Program, the 10-foot criterion will be reduced to 5 feet in the annual 3M evaluations subsequent to this initial evaluation. The 3M Program allows for an adjustment of the measurement-based value that may account for natural variation in water levels, as discussed below.

An adjustment for natural fluctuation in water levels is critical to a proper statistical evaluation of Test 1. Depending on which period of time is used to calculate the amount of natural water level variation from measured water levels, the resulting estimate of drawdown attributed to the mine may be either too large or too small. A one-year period of time, from August 1, 2006 to July 31, 2007, is used for calculations related to pre-mining conditions. For the current 3M evaluation, available water level data for Group 1 wells were used for calculating the average pre-mining water level and the pre-mining range of natural water level fluctuation for each well. The natural fluctuation range is calculated by subtracting the minimum measured pre-mining water level from the maximum measured pre-mining water level.

A one-month period of time, from June 1, 2008 to June 30, 2008 is used for calculations related to mining conditions as called for in the 3M Program[15]. Therefore, available water levels for Group 1 wells for this one-month period were used for calculating the average water level during the time period associated with mine pumping.

Estimated water level changes based on model predictions were calculated from the pumping and non-pumping simulations (Section 5.0). To calculate the model-projected magnitude of change due to mine-related pumping, the water level at the end of June 2008 for the pumping simulation was subtracted from the water level at the end of June 2008 for the non-pumping simulation.

Results of Test 1 (**Table 7**) indicate that, for each Group 1 well, the difference between the two values representing the estimated influence of mine-related pumping on the groundwater system is acceptable. According to the MMP, if the difference between these two values is less than the pre-mining range of natural water level fluctuations, the criterion for the test is presumed satisfied. Based on the successful results of Test 1, the decision analysis of the 3M process proceeds to the next step, Test 1A.

6.3 Description and Results of 3M Test 1A

Test 1A is intended to evaluate the difference between two values representing changes in horizontal hydraulic gradients due to the influence of groundwater pumping for mining purposes. The first value is

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[15] See Section 3, Exhibit 3, Appendix F of the FEIS; BLM, 2003

calculated from measured groundwater levels, whereas the second value is based on modeling results from the transient simulation. For this test, the change in hydraulic gradient over time is expressed as a percentage. For the model to pass the Test 1A criterion, the difference between the two percentages must be 50% or less. According to the 3M Program the 50% criterion will be reduced to 25% after the first 3M evaluation, with the expectation that the model would not be recalibrated until after the third year of mining operations, that is, beyond August 2010. Test 1A only applies to the following two pairs of wells in Group 1 (see Section 6.0 regarding the exclusion of wells LBF-01d and LBF-02d):

- LBF-01 and LBF-02

- LBF-03 and LBF-04

The 3M Program does not allow for an adjustment of the measurement-based value representing the magnitude of change in hydraulic gradient that could account for natural variations. Because the hydraulic gradients are a composite response to numerous factors, including fluctuations of the natural system and groundwater pumping for mining purposes, the computed gradients represent a composite measurement-based value for assessing the magnitude of overall change over the area of interest.

For each well pair, the measurement-based values of hydraulic gradients were calculated as follows. In accordance with the 3M Program, the pre-mining average water level from Test 1 for the southwestern well (LBF-02 or LBF-04) was subtracted from the pre-mining average water level from Test 1 for the northeastern well (LBF-01 or LBF-03). This water level difference is then divided by the distance in feet between the two wells in the well-pair under evaluation. A positive hydraulic gradient indicates an overall groundwater flow direction to the southwest. The hydraulic gradient value for the mining period is calculated similar to the pre-mining value except the average water levels for the mining period are used. Estimated hydraulic gradients based on model predictions were calculated similar to the measurement-based estimates using model-based average water levels at the model cells corresponding to each well location.

The percent change in hydraulic gradient over time is computed for each well pair from the estimates of hydraulic gradient for the pre-mining and mining periods[16]. This calculation is done for measurement-based values and model-based estimates of hydraulic gradient. The difference between the measurement-based and model-based change in hydraulic gradient, expressed in percent, is then computed and compared to the criterion of Test 1A.

The results of Test 1A indicate that the difference between the model- and measurement-based values of hydraulic gradient change over time are acceptable. **Table 8** provides a summary of results for Test 1A. Based on the successful results of Test 1A, the decision analysis of the 3M process proceeds to Test 2A instead of Test 2. Regarding Group 2 wells, note that Test 2 is not a requirement according to the 3M Program.

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[16] Percent change in gradient is computed by subtracting the June 2010 gradient from the June 2007 gradient, then dividing that difference by the June 2007 gradient, and then multiplying the result by 100 (Section 3, Exhibit 3, Appendix F of the FEIS; BLM, 2003). A positive percentage indicates a decrease in the gradient toward the southeast.

6.4 Description and Results of 3M Test 2A

The intent of Test 2A is similar to that of Test 1, except Test 2A applies to wells in Groups 4 and 5. The numerical criterion for Test 2A is 20 feet of water elevation difference for this first 3M evaluation, and 10 feet of water elevation difference thereafter. Unlike Test 1, the 3M Program does not allow for an adjustment of the measurement-based values of water level change that may account for natural variation in water levels.

For Test 2A, the most recent water level measured before mining commenced is used to represent pre-mining conditions. Similarly, conditions during mining operations are represented by the water level measured nearest the end of the evaluation period. For comparison to model prediction results, the simulated water level closest in time to the measured water level is used to represent pre-mining (i.e. non-pumping) and during-mining (i.e., pumping) conditions for each well and time period. To calculate the water level change, the selected water levels during the mining period are subtracted from the selected pre-mining water levels.

Results of Test 2A indicate an acceptable difference between the modeled estimates of water level change and the change in water level based on measurements for Group 4 and Group 5. **Table 9** provides a summary of results for Test 2A, which indicates that the statistical measure for each well group complied with the more stringent criterion of 10 feet scheduled to be implemented in the next annual evaluation. Because of the successful results of Test 2A, the decision analysis of the 3M process terminates at the conclusion of Test 2A. According to the 3M Program, monitoring continues for one year before a re-evaluation is conducted to assess possible further actions.

6.5 Summary of 3M Evaluation

An evaluation of the 3M Program for the 2007-2008 period has been conducted utilizing a slightly improved version of the 2002 FEIS Model to better represent groundwater conditions and responses to induced stresses. The results of the 3M evaluation for the 2007-2008 period, which are summarized in **Table 10**, indicate an acceptable difference between the model-estimated conditions and conditions based on measured water levels. According to the 3M Program, no recalibration of the model is required at this time. Monitoring will continue for one year before a re-evaluation is conducted to assess possible further actions.

7.0 Summary and Conclusions

The first annual evaluation of the 3M Program for the Safford Mine has been conducted and is presented in this report. The purpose of the 3M evaluation is to monitor the performance of improved versions of the 3M Model with regard to its ability to simulate the changes in water levels and hydraulic gradients over time as mining proceeds. The performance of the model is evaluated using a series of tests that compare differences between measurement-based values and model-based estimates of field conditions. The measurement-based values are calculated from data obtained from five groups of wells monitored for the 3M Program. The model-based estimates are obtained from a version of the 2002 FEIS Model that has been modified to more accurately simulate monthly average pumping based on actual pumping records for the mine. The 2002 FEIS Model represents the most recent calibration of the model.

The intent of the 3M Program is to provide a more reliable groundwater model from which predictions of the effects of the mine pumping on the groundwater system can be made. The available data indicate that there have not yet been enough stresses from pumping on the hydrogeologic system to allow a substantial improvement to the model at this time. The only benefit of recalibrating the model now would be to meet the Test 0, Comparison B criterion regarding hydraulic gradients. Based on the results of the 3M evaluation (excluding Test 0, Comparison B), the 3M Model performance is consistent with the site data obtained from the five groups of 3M wells. The overall conclusion of the current evaluation of the 3M Program is that the model does not need to be updated and recalibrated for the purposes of the 3M Program for at least one year.

Review of the water level data from the five groups of 3M wells indicates that the elevation of water levels have either been consistently increasing or decreasing based on spatial location, and that these two trends were established considerably prior to commencement of mining. The increasing and decreasing water level trends suggest that the regional groundwater system is in a natural dynamic state, adjusting to changing recharge, with no discernable influence to date from mine pumping, except in areas in close proximity to the production wells. Of particular interest, significant increases in the elevation of water levels in all of the Group 1 wells located closest to the Gila River have been recorded. The rise in water levels at these locations began more than two and a half years before groundwater pumping commenced at mine production wells GI-P1, GI-P2, GI-P4 and Shaft 1. The data analysis has revealed that natural water level fluctuations are, except for wells in close proximity to the pumping wells, up to approximately 10 times larger than model predicted drawdown from mine-related pumping. This has masked any effect on the groundwater system that may have been due to localized pumping related to the mine.

Water chemistry data support the hypothesis put forward in the MMP regarding the hydraulic isolation of the springs from the regional groundwater system. Since there is no evidence suggesting the springs are in significant hydraulic connection with the regional aquifer system, as noted in Section 3.3.1.4 of Appendix F of the FEIS, monitoring of the springs should be discontinued.

Actual pumping rates for the Safford Mine, both during the construction period and through the mining period included in this analysis (see **Table 2** of this report), have been substantially less than the estimated water demand rates shown in Section 2.1.2.2.1 of the FEIS, which were used in the 2002 FEIS Model for developing model simulated effects of mine development. Based on the actual water demand for the Safford Mine thus far, as well as current operating plans, the pumping rates for the foreseeable future are expected to be less than the rates previously used in the model to assess potential effects to the regional groundwater system, including potential effects to surface flows of the Gila River. See Sections 4.3.2.5.1 and 4.3.2.6.1 of the FEIS for additional background on the 2002 FEIS Model studies and results.

8.0 Selected References

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TABLES

Table 1. Summary of Information for Monitoring Wells in the 3M Program

3M Program Monitoring Well Group or Water-Chemistry Well	Well	Latitude[1] NAD 83 (degrees)	Longitude[1] NAD 83 (degrees)	3M Model Layer[2]	Altitude of Land Surface[3] (ft)	Open Intervals[1] (depth below land surface, ft)	Water Level[4]	Date of Water Level[5]
Group 1	LBF-01	32.93609	-109.71638	10	3,421.803	375-495	3,027.45	7/30/07
	LBF-01d	32.93614	-109.71632	13	3,422.756	915-1,015	3,027.88	7/30/07
	LBF-02	32.92716	-109.72342	10	3,297.256	250-370	3,027.12	7/30/07
	LBF-02d	32.92723	-109.72343	12	3,297.772	604-705	3,027.77	7/30/07
	LBF-03	32.92247	-109.6918	10	3,474.962	425-545	3,033.62	7/30/07
	LBF-04	32.91365	-109.69869	10	3,332.027	270-390	3,033.40	7/30/07
Group 2	AP-11	32.94751	-109.69914	11	3,681.041	790-1,200	3,123.59	6/25/07
	AP-12	32.95105	-109.68904	8	3,798.969	560-610	3,242.66	6/25/07
	AP-20	32.94291	-109.658	9	4,043.345	928-988	3,522.74	6/29/07
	AP-22	32.9363	-109.68451	9	3,670.456	652-752	3,043.46	6/25/07
	AP-23	32.93309	-109.66599	9	3,759.342	758-808	3,039.98	6/29/07
	AP-24	32.93244	-109.65722	8	3,836.358	640-740	3,155.15	6/29/07

	AP-26	32.92704	-109.67695	9	3,647.706	620-670	3,039.21	6/29/07
	AP-27	32.92097	-109.69728	9	3,415.721	430-480	3,037.33	6/28/07
	AP-28	32.91674	-109.68399	10	3,475.688	509-559	3,039.62	6/29/07
	AP-29	32.9172	-109.66906	9	3,504.295	518-568	3,039.49	6/29/07
	AP-30	32.92778	-109.64711	6	3,824.308	250-300	3,750.00	6/29/07
	AP-34	32.93141	-109.70094	13	3,489.43	1,150-1,200	3,036.62	6/29/07
	DPW-01	32.95543	-109.70943	9	3,696.617	565-605	3,175.38	6/26/07
	DPW-03	32.93642	-109.67442	9	3,839.96	800-910	3,041.77	6/29/07
	DPW-07	32.9408	-109.71151	10	3,509.548	685-735	3,033.81	6/26/07
	DPW-08	32.91893	-109.72562	10	3,217.952	310-345	3,031.17	6/26/07
	DPW-10	32.93931	-109.75478	11	3,246.617	535-565	3,028.00	6/26/07
	DPW-11	32.93364	-109.74049	10	3,274.092	340-370	3,029.01	6/26/07
	DPW-12	32.92461	-109.7557	12	3,093.238	610-650	3,025.43	6/26/07
	DPW-13	32.91929	-109.74129	12	3,144.463	510-540	3,027.76	6/26/07
	DPW-15	32.929	-109.68775	10	3,575.524	770-800	3,038.49	6/29/07

	DPW-16	32.93148	-109.70099	11	3,489.616	770-800	3,037.02	6/29/07
Group 3	AP-01	32.973	-109.68429	5	4,167.092	497-608	3,974.29	6/26/07
	AP-02	32.96882	-109.67673	4	4,166.612	280-330	4,094.90	6/29/07
	AP-3A	32.97078	-109.65844	4	4,498.23	585-635	No Data	No Data
	AP-09	32.96171	-109.65821	3	4,273.178	135-185	4,185.76	6/26/07
	AP-10	32.95506	-109.64884	7	4,188.046	747-797	3,892.89	6/29/07
	AP-21	32.94071	-109.64774	4	4,089.629	258-308	3,948.26	6/26/07
	AP-25	32.93774	-109.65431	5	3,919.524	255-315	3,907.23	6/25/07
	AP-32	32.95951	-109.66263	5	4,185.191	408-458	3,884.46	6/26/07
	DPW-05	32.96892	-109.66833	10	4,290.937	1,320-1,370	3,971.68	6/26/07
	DPW-06	32.95591	-109.65458	7	4,159.725	700-750	4,070.43	6/26/07
Group 4	GI-T18	32.98311	-109.71113	9	4,153.553	1,236-1,614 1,724-2,501	3,250.89	6/26/07
	GI-T20	32.98753	-109.70342	6	4,302.121	492-1,092	3,814.36	6/26/07
	GI-T25	32.98037	-109.69494	5	4,335.144	200-1,320	4,104.47	6/26/07
	GI-T34	32.97332	-109.72002	11	3,925.887	645-2,489	3,257.58	6/26/07

	GI-T38	32.99575	-109.71974	8	4,374.871	500-1,919	3,833.14	6/26/07
Group 5	G5-01A	33.03156	-109.70211	1	5,089.749	278-478	4,884.25	6/26/07
	G5-01B	33.00588	-109.69841	3	4,568.338	358-458	4,475.95	6/26/07
	G5-02	32.93966	-109.58834	6	4,418.456	770-870	3,841.20	6/29/07
	RB-1	33.04295	-109.70973	2	5,699.193	1,070-1,270	4,858.39	6/26/07
Wells Sampled for Water Chemisty[6]	AP-14	32.95192415	-109.678163	8	3,970.25	729-779	3,244.88	December, 1997
	AP-05	32.95809079	-109.6993302	8-9	3,765.80	560-660	3,248.53	1/14/98
	DPW-02	32.9721185	-109.7500813	8[a]	4,095.79	845-925	3,252.54	3/10/98
	GI-P1	32.5719	-109.412301	9-11[a]	3,853.53	887-1070	3,253.48	8/14/96

[1] Obtained from http://nwis.waterdata.usgs.gov.

[2] URS Corporation, 2002, Appendix B.

[3] Data for 3M wells obtained from http://nwis.waterdata.usgs.gov; data for water-chemistry wells obtained from URS Corporation, 2002, Table 2-1.

[4] Data for 3M wells obtained from http://nwis.waterdata.usgs.gov; data for water-chemistry wells obtained from URS Corporation, 2002, Table 2-2.

[5] Mining commenced August 2007.

[6] These water-chemistry wells are not part of the 3M Program evaluation described in Section 6, however some 3M wells are sampled for water chemistry.

[a] Data obtained from 3M Model.

Table 2. Monthly Average Pumping Rate from March 2006 to June 2008

Date	Monthly Average Pumping Rate (gpm)				
	GI-P1	GI-P2	GI-P4	Shaft 1	Total Rate
March, 2006	0.0	0.0	5.1	0.0	5.1
April, 2006	0.0	0.0	6.0	0.0	6.0
May, 2006	0.0	0.0	14.3	0.0	14.3
June, 2006	0.0	0.0	14.3	0.0	14.3
July, 2006	0.0	0.0	14.3	0.0	14.3
August, 2006	0.0	0.0	14.3	0.0	14.3
September, 2006	12.9	0.0	14.3	0.0	27.2
October, 2006	16.0	0.0	14.2	0.0	30.1
November, 2006	13.4	0.0	11.8	0.0	25.1
December, 2006	8.5	0.0	8.5	0.0	17.0
January, 2007	10.7	0.0	10.7	0.0	21.4
February, 2007	12.0	0.0	11.8	0.0	23.8
March, 2007	20.9	0.0	21.3	0.0	42.2
April, 2007	27.2	0.0	25.6	5.0	57.8
May, 2007	29.1	0.0	23.6	18.0	70.7
June, 2007	27.1	0.0	19.0	38.0	84.1
July, 2007	20.9	0.0	17.9	5.6	44.5
August, 2007[a]	7.6	0.0	6.7	76.9	91.2
September, 2007	0.0	0.3	0.0	68.2	68.6

October, 2007	1.3	1.7	20.0	25.8	48.9
November, 2007	11.7	17.5	6.6	9.0	44.7
December, 2007	130.3	365.9	465.7	0.0	961.9
January, 2008	145.8	532.1	736.9	0.0	1,414.9
February, 2008	178.5	448.9	1,127.7	132.3	1,887.3
March, 2008	311.0	324.8	1,066.7	365.7	2,068.2
April, 2008	554.5	551.8	509.5	530.8	2,146.7
May, 2008	622.6	373.0	438.4	541.6	1,975.6
June, 2008	556.9	277.6	1,411.2	290.2	2,535.9

[a] Mining commenced August 2007.

Table 3. Approximate Magnitude of Water Level Fluctuations and Water Level Change for the 3M Evaluation Period

3M Program Monitoring Well Group Number	Well	Short-Duration Water Level Fluctuation[a] (ft)	Long-Duration Water Level Fluctuation[b] (ft)	Estimated Change in Water Level For Evaluation Period[c] (ft)	Notes[d]
Group 1	LBF-01	0.4	1	0.1	1, 2
	LBF-01d	0.4	1	0.2	1, 2
	LBF-02	0.3	1	0.1	1, 2
	LBF-02d	0.3	1.5	0.1	1, 2
	LBF-03	0.3	1.5	0.1	1, 2
	LBF-04	0.6	0.5	0.2	1, 2
Group 2	AP-11	0.4	-6	-0.8	1, 2, 9
	AP-12	0.1	-30	-20.0	3
	AP-20	0.2	-6	-1.0	1, 2
	AP-22	0.4	1.5	-1.6	1, 2, 5, 9
	AP-23	0.2	1.5	-0.2	1, 2
	AP-24	0.4	-32	8.8	1, 2, 4
	AP-26	0.2	1.5	-0.1	1, 2
	AP-27	0.4	1.5	0.0	1, 2
	AP-28	0.2	1	0.0	1, 2
	AP-29	0.4	1.5	0.1	1, 2
	AP-30	1.4	-6	-0.8	1, 2
	AP-34	0.4	1	0.0	1, 2

	DPW-01	0.4	-6	-0.8	1, 2
	DPW-03	0.2	0	-0.2	1, 2
	DPW-07	0.4	1.5	0.4	1, 2
	DPW-08	1.0	2	0.1	1, 2
	DPW-10	0.5	2	0.2	1, 2
	DPW-11	0.5	2	0.1	1, 2
	DPW-12	0.7	1.5	0.2	1, 2
	DPW-13	0.8	1.5	0.1	1, 2
	DPW-15	0.4	1.5	-0.1	1, 2
	DPW-16	0.4	1.5	0.0	1, 2
Group 3	AP-01	0.4	---	---	5
	AP-02	1	-10	4.9	6
	AP-3A	---	---	---	7
	AP-09	6	0	-0.5	2
	AP-10	0.4	-15	-2.4	1, 2
	AP-21	5	---	---	5
	AP-25	10	-5	-7.5	2, 8, 9
	AP-32	0.4	-6	-1.8	1, 2
	DPW-05	0.3	-3	-4.6	5
	DPW-06	0.4	-4.5	-0.4	1, 2
Group 4	GI-T18	0.4	-12.5	-8.3	1
	GI-T20	0.6	-7.5	-1.6	1, 2

	GI-T25	0.5	-2.4	11.6	6
	GI-T34	0.5	-2	-1.3	1, 2
	GI-T38	0.4	-2.5	-0.9	1, 2
Group 5	G5-01A	0.4	-9	-1.9	1, 2
	G5-01B	3.5	0	-2.4	1, 2
	G5-02	0.3	0.8	0.5	1, 2
	RB-1	0.5	0.2	1.3	1, 2

[a] Short duration fluctuations are representative of less than one day to several days. Fluctuations are approximate values based on data collected prior to August 2007 (pre-mining).

[b] Long duration fluctuations represent approximate net change based on data collected since monitoring for the 3M Program began. A negative value indicates a declining water-level trend.

[c] Water-level change equals the water level for last month of the 3M evaluation period (June 2008) subtracted from the average or representative water level for the month preceding the start of mining (July 2007). A negative value indicates that the June 08 water level is lower than the July 07 water level.

[d] Notes:

1. Water-level trend (rising or falling) established prior to start of mining
2. Natural fluctuation (a or b) is larger than estimated change (c).
3. Located near pumping wells GI-P1 and GI-P4.
4. Unusual water level trend and fluctuations.
5. Water level is strongly influenced by water chemistry sampling events; recovery takes 1 to 2 (or more) years.
6. Unusual water level fluctuations.
7. Insufficient data.
8. Water level influenced by sampling.
9. Well is used in the Aquifer Protection Permit program.

Table 4. Discharge Rates and Conditions of Springs

Spring	Description of Conditions or Amount of Measured Discharge in Gallons per Minute (gpm)	
	2005	2007
Cottonwood	No Data[1]	0.5 gpm
Bear	Dry	Dry
Bryce	Dry	0.53 gpm
Hackberry	Springbox[2]	Springbox[2]
Big	Springbox[2]	0.36 gpm
Pothole	Dry	Amount of discharge too small to measure
Walnut	Springbox[2]	Springbox[2]

[1] No information was collected.

[2] Standing water in springbox; amount of discharge could not be measured.

Table 5. Summary of Results of the Wilcoxon-Mann-Whitney Tests

| Analyte | Year of Sample Event | Type of Water | Raw Statistics | | | | | | | | Wilcoxon-Mann-Whitney (WMW) Test[1] | | | | | |
			Number of Valid Observa-tions	Number of Distinct Observa-tions	Minimum	Maximum	Mean	Median	Standard Deviation	Standard Error of the Mean	Site Rank Sum W-Statistic	WMW Test U-Statistic	Lower Critical Value (0.001)	Upper Critical Value (1.000)	Approx-imate P-Value	Statistical Conclusion
pH	2005	Spring Water	4	4	6.62	7.34	6.963	6.945	0.296	0.148	159	54	N/A[2]	N/A[2]	0.00677	Reject Null Hypothesis[3] (H0)
		Groundwater	14	14	7.18	10.52	7.918	7.545	0.963	0.257						
	2007	Spring Water	6	6	6.19	7.08	6.728	6.735	0.308	0.126	169	78	N/A[2]	N/A[2]	0.000734	Reject Null Hypothesis[3] (H0)
		Groundwater	13	11	7.26	10.22	7.998	7.67	0.897	0.249						
Carbon-14	2005	Spring Water	4	4	70.3	104.2	90.08	92.9	14.41	7.207	106	1	N/A[2]	N/A[2]	0.0035	Reject Null Hypothesis[3] (H0)
		Groundwater	14	14	2.9	80.9	34.16	35.45	21.91	5.856						
	2007	Spring Water	6	6	82.65	109.9	98.49	101	10.81	4.414	91	0	N/A[2]	N/A[2]	0.000531	Reject Null Hypothesis[3] (H0)
		Groundwater	13	13	4.6	82.08	36.38	37.64	21.88	6.068						

[1] Test Specifications:

- Confidence Coefficient = 99.9%
- Selected Null Hypothesis (H0) = "Spring Water Mean/Median is Equal to Groundwater Mean/Median" (Two Sided Alternative)
- Alternative Hypothesis = "Spring Water Mean/Median is Not Equal to Groundwater Mean/Median"

[2] "Not Applicable"

[3] Conclude spring water is statistically different than groundwater (see footnote 1)

Table 6. Monthly Average Pumping Rate Simulated in 2008 3M Model

Month	Monthly Average Pumping Rate (gpm)					
	GI-P1	GI-P2	GI-P4	Shaft 1	GI-P3	Total Rate
June, 1996	0.0	533.3	0.0	0.0	0.0	533.3
July, 1996	0.0	45.7	0.0	0.0	0.0	45.7
August, 1996	0.0	1,981.9	0.0	0.0	0.0	1,981.9
September, 1996	0.0	2,290.6	2,717.1	0.0	1,138.9	6,146.6
October, 1996	348.4	2,000.0	3,200.0	0.0	1,000.8	6,549.2
November, 1996	0.0	1,029.6	3,200.0	0.0	0.0	4,229.6
December, 1996	0.0	0.0	1,423.9	0.0	0.0	1,423.9
January, 1997 To February, 2006	0.0	0.0	0.0	0.0	0.0	0.0
March, 2006	0.0	0.0	5.1	0.0	0.0	5.1
April, 2006	0.0	0.0	6.0	0.0	0.0	6.0
May, 2006	0.0	0.0	14.3	0.0	0.0	14.3
June, 2006	0.0	0.0	14.3	0.0	0.0	14.3
July, 2006	0.0	0.0	14.3	0.0	0.0	14.3
August, 2006	0.0	0.0	14.3	0.0	0.0	14.3
September, 2006	12.9	0.0	14.3	0.0	0.0	27.2
October, 2006	16.0	0.0	14.2	0.0	0.0	30.1
November, 2006	13.4	0.0	11.8	0.0	0.0	25.1
December, 2006	8.5	0.0	8.5	0.0	0.0	17.0

January, 2007	10.7	0.0	10.7	0.0	0.0	21.4
February, 2007	12.0	0.0	11.8	0.0	0.0	23.8
March, 2007	20.9	0.0	21.3	0.0	0.0	42.2
April, 2007	27.2	0.0	25.6	5.0	0.0	57.8
May, 2007	29.1	0.0	23.6	18.0	0.0	70.7
June, 2007	27.1	0.0	19.0	38.0	0.0	84.1
July, 2007	20.9	0.0	17.9	5.6	0.0	44.5
August, 2007	7.6	0.0	6.7	76.9	0.0	91.2
September, 2007	0.0	0.3	0.0	68.2	0.0	68.6
October, 2007	1.3	1.7	20.0	25.8	0.0	48.9
November, 2007	11.7	17.5	6.6	9.0	0.0	44.7
December, 2007	130.3	365.9	465.7	0.0	0.0	961.9
January, 2008	145.8	532.1	736.9	0.0	0.0	1,414.9
February, 2008	178.5	448.9	1,127.7	132.3	0.0	1,887.3
March, 2008	311.0	324.8	1,066.7	365.7	0.0	2,068.2
April, 2008	554.5	551.8	509.5	530.8	0.0	2,146.7
May, 2008	622.6	373.0	438.4	541.6	0.0	1,975.6
June, 2008	556.9	277.6	1,411.2	290.2	0.0	2,535.9

Table 7. Results for 3M Test 0

Well	Comparison A*: Difference Between the Average of Observed Water Levels in the Monitored Group 1 Well-Pairs and the Corresponding Average Projected Steady-State Modeled Water Levels (ft)	Well-Pair	Comparison B*: Percent Difference Between Observed and Modeled Hydraulic Gradients for each LBF Well-Pair (%)	3M Criteria[2] and Result If Comparison A Values Are Greater Than 30 Feet Or If Comparison B Values Are More Than 25%, Then Recalibrate Model To Bring The Projected Levels And Gradients Within The Test 0 Bounds. Then Update Predictions, Re-do 3M Calculations, And Evaluate Need For Changing Mitigation Based On Updated Results.
LBF-01	28	LBF-01 : LBF-02	-146	Water-level differences (A) for the LBF wells are less than 30 feet. Differences in hydraulic gradient (B) are greater than 25%. See Section 6.1 regarding Comparison B. Go to Test 1.
LBF-02	28			
LBF-03	25	LBF-03 : LBF-04	-851	
LBF-04	23			

* Evaluation is performed on Well Group 1 for the Pre-Mining Period. Conclusions of the 3M evaluation are summarized in Table 11.

Table 8. Results for 3M Test 1

Well	Difference Between Measurement-Based and Model-Based Water-Level Changes, Less Pre-Mining Annual Water Level Fluctuation, for Each LBF Well Since the Last Model Calibration[1] (ft)	3M Criteria and Result If Any Values Are Greater Than 5 feet, Then Go To Test 2; Otherwise Go To Test 1A
LBF-01	0.0	Go To Test 1A
LBF-02	0.0	
LBF-03	0.0	
LBF-04	0.0	

[1] Evaluation is performed on Well Group 1 for the period from commencement of mining through June 2008 (Evaluation Period). If the pre-mining fluctuation is greater than the change between July 2007 and June 2008, the water-level change, if any, related to mining is not measureable, and assumed to be zero, for the evaluation period. Conclusions of the current 3M evaluation are summarized in Table 11.

Table 9. Results for 3M Test 1A

Well-Pair	Difference in Percent Change of Measurement-Based Estimated and Modeled Hydraulic Gradients for each LBF Well-Pair Since the Last Model Recalibration[1] (%)	3M Criteria and Result If Any Values Are Greater Than 25%, Then Go To Test 2; Otherwise Go To Test 2A.
LBF-01 : LBF-02	-9	Go To Test 2A
LBF-03 : LBF-04	12	

[1] Evaluation is performed on Well Group 1 for the period from commencement of mining through June 2008 (Evaluation Period). Gradients are calculated based on averages of measured water levels. Negative values are due to an increase in the measurement-based hydraulic gradient towards the southwest. Conclusions of the current 3M evaluation are summarized in Table 11.

Table 10. Results for 3M Test 2A

Well Group	Well	For Each Group 4 & 5 Well, Calculated Absolute Value of the Difference Between Measurement-Based and Modeled Water-Level Change[1] (ft)	Computed Average Value of the Difference for Group 4 and 5 Wells (ft)	3M Criteria and Result If Any Value Is More Than 10 Feet, Then Recalibrate The Model, Run The Mining Period Prediction, And Adjust The Mitigation As Necessary, And Wait One Year And Re-Evaluate; Otherwise Wait One Year And Re-Evaluate
4	GI-T18	8.2	**4.7**	Wait one year and re-evaluate.
4	GI-T20	1.6		
4	GI-T25	11.6		
4	GI-T34	1.1		
4	GI-T38	0.9		
5	G5-01A	1.9	**1.5**	
5	G5-01B	2.4		
5	G5-02	0.5		
5	RB-1	1.3		

[1] Evaluation is performed on Well Groups 4 and 5 for the period from commencement of mining through June 2008 (Evaluation Period). The estimated change in water level based on measured water levels has not been adjusted for natural fluctuations. Conclusions of the current 3M evaluation are summarized in Table 11.

Table 11. Summary of Results for the Preliminary 2007-2008 3M Evaluation

Test	Evaluation Period	Well Group	3M Statistic	3M Criteria[1]	Result
0	Pre-Mining	1	Comparison A Difference between the average of measured water levels in the monitored Group 1 well pairs (after development and recovery of the wells) and the corresponding average steady-state modeled water levels. Comparison B Percent difference between measurement-based and model-based estimated hydraulic gradients for each LBF well pair.	Comparison A If any values are greater than 30 ft or Comparison B If any values more than 25%, then: Recalibrate Model to bring the projected levels and gradients within the Test 0 bounds. Then update predictions, re-do 3M calculations, and evaluate need for changing mitigation based on updated results.	Water-level differences for the LBF wells are less than 30 feet. Differences in hydraulic gradient are greater than 25%. See Section 6.1 regarding Comparison B. Go to Test 1.
1	Pre-Mining and 1st Evaluation Period	1	Difference between the measurement-based and model-based estimates of transient water-level change, less the pre-mining annual water level fluctuation[2], for each LBF well since last model calibration.	If any values are greater than 10 feet, then go to Test 2; otherwise go to Test 1A.	All values are much less than 10 feet (go to Test 1A).
1A	Pre-Mining and 1st Evaluation Period	1	Difference in percent change in transient measurement-based and model-based estimates of hydraulic gradients for each LBF well pair, less the pre-mining gradient fluctuation[2], since the last model recalibration.	If any values are greater than 50%, then go to Test 2; otherwise go to Test 2A.	All values are much less than 50% (go to Test 2A).

2	Pre-Mining and 1st Evaluation Period	2	Mean value of percent difference between measurement-based and model-based estimated water-level change.	If the value is more than 30%, then recalibrate the model, run the mining period prediction, and adjust the mitigation as necessary. Also, wait one year and re-evaluate. Otherwise go to Test 2A.	Not evaluated.
2A	Pre-Mining and 1st Evaluation Period	4 & 5	Average of absolute differences between measurement-based and model-based estimates of water-level changes.	If the value for either well group is more than 20 feet, then recalibrate the model, run the mining period prediction, and adjust the mitigation as necessary. Also, wait one year and re-evaluate. ; Otherwise wait one year and re-evaluate.	For Group 4 and 5, the average values are less than 5 feet. **Final Result: <u>Wait one year and re-evaluate.</u>**

[1] After the first 3M evaluation, all listed 3M Criteria will be 50% smaller unless the 3M Program is modified. See Section 6.1 regarding the Criterion for Test 0, Comparison B.

[2] To account for and remove natural fluctuations not caused by mining.

FIGURES

APPENDIX A

ATTACHMENT 1

ATTACHMENT 2